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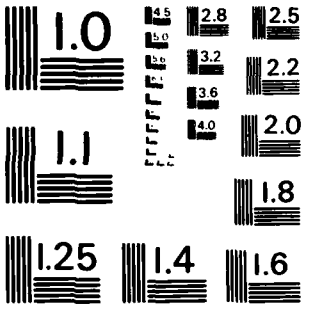

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A SUMMARY OF
RESEARCH ON MICROPROCESSOR NETWORKS

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May 1983

Final Technical Report

ONR Contract N00014-77-C-0714

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the achievements of research that led to the development of a new programming concept for computer networks, known as Distributed Processes. This new concept had considerable influence on the subsequent development of the programming language Ada by the Department of Defense.

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INTRODUCTION

This is the final technical report of a research project entitled "DESIGN OF PROGRAMMING LANGUAGES AND MACHINE ARCHITECTURES FOR RELIABLE MICROPROCESSOR NETWORKS." The report summarizes the achievements of research at USC supported under ONR Contract No. N00014-77-C-0714 (NR no. 048-647).

The goal of the research was to develop a design methodology that will make the software and hardware structure of microprocessor networks and multiprocessors simple, reliable and efficient.

MICROPROCESSOR COMPARISON

As a first step, we invented a simple method for comparing the instruction sets of existing 16-bit microprocessors to see how efficient they are for implementing a block structured programming language, such as Pascal or Concurrent Pascal.

We identified the most frequently executed virtual instructions generated by the Concurrent Pascal compiler and wrote the corresponding machine code for six different microprocessors. These code pieces were used to estimate the overall performance of each microprocessor compared to the PDP 11/45 minicomputer. This method enabled us to compare the performance of microprocessors realistically by means of programming manuals only without running any benchmarks.

The results were described in a technical report [1] and in a paper published in Software - Practice and Experience [2].

MICROCOMPUTER SYSTEM

Our comparison of 16-bit microprocessors showed the DEC LSI-11 to be the fastest one that was commercially available in 1978. An LSI-11 microcomputer with a terminal and a dual diskette drive was aquired in 1979. The use of this computer is described below.

COMPUTER NETWORK SURVEY

Charles Hayden wrote a working document which surveyed existing multicomputer systems [3]. His study of the literature was supplemented by visits to Carnegie-Mellon University and the Honeywell Research Center.

PROGRAMMING LANGUAGE SURVEY

In November 1978 I delivered a keynote address on concurrent programming at the IEEE Computer Software and Applications Conference [4]. This paper summarizes the first 20 years of concurrent programming (1958-78) and identifies the major development phases of the field as an initial hardware challenge followed by a software crisis, a conceptual innovation and subsequent programming language development which, in turn, led to formal understanding and hardware refinement. The paper also describes the new concepts of concurrent programming developed by Dijkstra, Hoare and myself during the 1970's. The keynote address was later reprinted in Computer (1979) and Selected Reprints in Software from Computer (1980).

These results concluded our survey and evaluation of existing hardware and software technology for microprocessor networks.

MULTIPROCESSOR ARCHITECTURE

The first original contribution of our research was a proposed multiprocessor architecture for concurrent programs written in languages similar to Concurrent Pascal. Each processor has a local store dedicated to a single process. The processors share a common store that contains the monitors used for process communication.

This multiprocessor architecture was presented in a paper at the ACM 78 Conference in December 1978 [5]. The paper appeared simultaneously in the ACM Architecture News.

DISTRIBUTED PROCESSES

The most significant contribution of the research was a new programming language concept, called distributed processes, which enables microprocessors to communicate by means of synchronized procedure calls. This new idea, which unifies the process and monitor concepts, was published in Communications of the ACM (Nov. 1978) [6] and was later reprinted in two IEEE Tutorials on Software Design Strategies (1981) and The Ada Programming Language (1983). It was also translated into Japanese.

Distributed processes and Hoare's Communicating Sequential Processes were the first programming language proposals oriented towards distributed processing on computer networks. The new programming language Ada developed by the Department of Defense was strongly influenced by the concept of Distributed Processes. In a

paper on "Parallel Processing in Ada," two of the designers of Ada, O. Roubine and J.-C. Heliard, remarked that "Brinch Hansen's proposal seemed to fit our needs to a good extent and was a source of inspiration in the design of the Ada tasking facilities."

THE PROGRAMMING LANGUAGE JOYCE

In November 1979 I published a report on an experimental programming language Joyce which includes distributed processes [7]. This language was intended for real-time applications controlled by computer networks without common storage.

Charles Hayden wrote a compiler and system kernel for the Joyce language and used them to experiment with a variety of concurrent programs on the LSI-11 microcomputer. The compiler was written in Pascal and ran under a Concurrent Pascal system on a PDP 11/55 minicomputer. Compiled programs were moved to the LSI-11 microcomputer and executed using diskettes as the transfer medium between the two computers.

PROJECT TERMINATION

In 1980, ONR was unable to fund a continuation of this work and the research stopped.

PUBLICATIONS

This research has led to the following working documents, technical reports and published papers:

1. Brinch Hansen, P., and Hayden, C., Microcomputer Evaluation. Computer Science Department, University of Southern California, Los Angeles, CA, January 1978.

2. Brinch Hansen, P., and Hayden, C., Microcomputer Comparison. Software - Practice & Experience 9, (March 1979), 211-17.

3. Hayden, C., A Survey of Multiple Computer Systems. Computer Science Department, University of Southern California, Los Angeles, CA, September 1978, (Internal working document).

4. Brinch Hansen, P., A Keynote Address on Concurrent Programming. IEEE Computer Software & Applications Conference. Chicago, IL, November 1978. Reprinted in (1) Computer 12, 5 (May 1979), 5-56; (2) Selected Reprints in Software from Computer, 1980.

5. Brinch Hansen, P., Multiprocessor Architectures for Concurrent Programs. ACM Conference 1978, Washington, DC, December 1978. Reprinted in the ACM Architecture News, December 1978.

6. Brinch Hansen, P., Distributed Processes: A Concurrent Programming Concept. Comm. ACM 21, 11 (November 1978), 934-41. Reprinted in (1) IEEE Tutorial on Software Design Strategies, 1981; (2) The Ada Programming Language: A Tutorial, 1983. Translation: Japanese.

7. Brinch Hansen, P., Joyce: A Language for Computer Networks. Computer Science Department, University of Southern California, Los Angeles, CA, November 1979.

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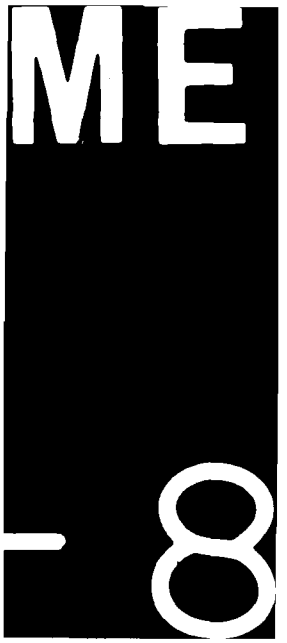
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